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FACTORS INFLUENCING THE NUTRITIVE VALUE OF THE TOMATO

A REVIEW OF THE LITERATURE

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INTRODUCTION

The tomato is one of the most important "protective foods," both because of its special nutritive values and also because of its large and widespread production. Smith (*118*)[2] lists tomatoes as the third largest of the vegetable crops, being exceeded only by potatoes and sweetpotatoes. Among the canned vegetables, the tomato ranks first.

In 1939, according to United States Department of Agriculture Agricultural Statistics (*132*), 655,981 tons of tomatoes were produced for fresh market and 1,999,900 tons for processing. The excess of imports over exports, for all purposes, was 36,479 tons. These figures give a total of 2,692,360 tons available for consumption. Complete data as to the actual consumption, which of course is considerably less than the production, are not available. Among the processed products canned tomatoes rank first, followed by juice, ketchup, and smaller amounts of other products.

The outstanding value of the tomato as a source of special nutrients needed in the diet is indicated in the call of the Secretary of Agriculture for a 50 percent increase in the production of tomatoes in 1941 to help correct malnutrition in this country and for export under the lend-lease program, and production up to the limit of processing and an acreage increase of 27 percent over the 1941 figure set as the goal in the 1942 Food for Freedom Program. Published analyses indicate that tomatoes from different sources vary rather widely in their content of the nutrients of special importance. It is the object of this publication to review and summarize the experimental work that provides information regarding factors related to these variations.

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[1] Located at Ithaca, N. Y.
[2] Italic numbers in parentheses refer to Literature Cited, pp. 16–23.

TOTAL SOLIDS, ACIDITY, PIGMENTS

The tomato fruit contains on the average about 7 percent dry matter, but the amount varies considerably depending upon many factors. Various investigators working with tomato pulp[3] have found a direct relationship between the refractive index and the amount of total solids present.

Saywell and Cruess (*107*) have reviewed the previous work and have shown from their studies, as well as from the work of others, that the refractive index may be used as a means of calculating total solids in tomato pulp by the use of a specific formula. The same authors found that the content of total solids of tomatoes of a given variety grown in a cool, foggy climate was higher than for the same variety grown in a warmer and drier climate. They also found that tomatoes grown in southern California had a lower percentage of dry matter than those produced in northern California. In general, the higher the summer temperature, the lower was the content of total solids. Their results indicate that California-grown tomatoes had a higher total-solids content than those grown in the eastern part of the United States. The solids content varied with the season and usually was somewhat higher in the late fall. A low water supply to the soil increased the dry matter content. The locular material[4] was lower in total solids than were the cores and walls. Tomatoes from adjacent plants and from different locations on a single plant varied markedly in dry matter, and considerable variation was found between varieties; certain varieties consistently producing more dry matter than others.

Smith (*118*) found that the total solids increased in hot, dry weather and decreased slightly after rains. It seems likely that this increase is correlated more with water supply than with temperature, since, as mentioned above (*107*), a cool climate favored dry matter accumulation, and since Lee and Sayre (*69*) in experiments in pots in the greenhouse found that total solids of four varieties varied approximately between 6 and 8 percent when the moisture supply was high (with the higher values toward the end of the season) and that a low moisture supply resulted in a marked increase in solids (up to more than 11 percent in one case). Differences between varieties were greater under conditions of low moisture supply. Bohart (*11*) has reported on the total solids of canned tomato juices.

These reports indicate that the solids content of tomatoes might be expected to vary between 6 and 8 percent and that under differing environmental conditions ranges of from 5 to 9 percent would not be uncommon. Reports of percentages from 4 to 11 are to be found in the literature. These variations in content of total solids are relatively great when considered on the percentage basis, since in some cases the total-solids content may be twice as high as in others. However, the extreme values for percentage of solids content that have been recorded seem to be found in fruits of little commercial value (*107*).

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[3] The red, pulpy portions, in finely divided form, of the whole tomato fruit, screened free of skin, seeds, and coarse fiber.

[4] In this and in subsequent mention of locular material, reference is made to the jellylike material and the juice minus the seeds.

The total solids of the tomato consist principally of carbohydrates, particularly reducing sugars. Various reports indicate variations in reducing-sugar content ranging from 2.3 to 4.5 percent on the fresh-weight basis, with an average of about 3.5 percent. The reducing-sugar content increases during ripening (*6, 100, 107, 108*). Beadle (*6*) found that fruits that ripened first in the season had the highest sugar content and that premature picking resulted in a lowered sugar content, even though the fruit subsequently ripened off the vine. Studies by Smith (*118*) showed that invert sugar increased or remained high when the temperature was high and decreased slightly following a rain. This worker (*117*) reported a significant correlation between temperature, expressed in degree-days, and invert sugar of Marglobe tomatoes. The tissues of the core of the fruit have been reported (*108*) to contain relatively high proportions of reducing sugars, total solids, and acid hydrolyzable matter, but the locular material was lower in amounts of these constituents than any other part of the fruit. Most reports agree that the sucrose content of tomatoes is very low (*107, 108, 118*), probably in most cases below 0.05 percent on the fresh-weight basis, although Smith (*118*) reports that it may reach as high as 1.5 percent. Starch content is also very low in ripe tomatoes, usually less than 0.05 percent (*100, 107, 108*).

Saywell and Cruess (*107*), conducting a large number of analyses covering three seasons, found an average protein content of 0.97 percent in fresh tomatoes. The variations ranged from 0.55 to 1.65 percent, and usually a high protein content was correlated with a high total-solids content. Bohart (*11*) reports the protein content to be 0.92 percent. Tomatoes contain less than half as much fat (ether extract) as protein.

The carbohydrates, protein, and fat of the tomato combine to give it a calorific value of approximately 23 calories per 100 grams of fresh material, due principally to the sugars present. While the tomato ranks high among vegetables in available calories per unit of dry matter, the amounts actually consumed do not make any substantial contribution to the energy needs of the diet, because so little dry matter is present.

The tomato is strongly acid, and this property is important in protecting the vitamin content against loss, particularly in cooking and canning. The general agreement between various authors as to the pH of ripe tomatoes is remarkably close. Smith (*118*) reports a range in pH of from 4.06 to 4.60; Bohart (*11*) from 4.29 to 4.59; Saywell and Cruess (*107*) from 3.8 to 4.4; and Rosa (*100*) from 4.1 to 4.5. With the exception of a single report (*17*), authors are generally in agreement that the usual pH range of tomatoes is between 4 and 4.5.

Although the range of pH found in tomatoes is not great, numerous reports indicate variations in total acidity. Rosa (*100*) and Chevalier and Suisse (*17*) report that during the ripening process there is a decrease in total acidity. According to Smith (*118*), the acidity decreased when the temperature was high and increased immediately following a rain. Lee and Sayre (*69*) found that drought conditions resulted in higher acid content of tomato fruits when compared with plants supplied with a normal amount of water. The acid content was high at the beginning of the season, low in the middle, and high again at the end. Bohart (*10*) reports green tomatoes somewhat more acid than partially or fully ripe ones, but there were some indications of a slight increase in acidity in the fully matured fruit as compared with the partially colored fruit. Saywell and Cruess (*107*) made extensive studies of total acidity of California grown tomatoes. Their results show a consistent difference in total acid between several varieties and a wide range of variation between the fruits of individual plants of a given variety. The locular material was higher in total acid than were the cores or walls. The acidity is apparently caused chiefly by citric acid. Borntraeger (*13*) reports that oxalic acid, if present at all in sound ripe tomatoes, occurs only in amounts so small as not to be injurious to animals or to invalid humans, and that glycollic acid is not present. Sandor (*105*) reports the presence of an appreciable amount of volatile acids in ripe tomatoes, which increase in quantity upon storage.

Although the pigments of the tomato (aside from carotene) have no known nutritional significance, they do play an important role in market demand. This is particularly true for lycopene. Several investigations (*14*, *28*, *124*) have dealt with the pigments present in tomatoes. The earlier work has been corroborated and extended by Vogele (*136*) in a comprehensive report. He carefully analyzed the color qualities of fruits produced under different environmental conditions and concluded that the optimum temperature for lycopene formation was 24° C. None was formed at temperatures above 30°, with the result that at temperatures from 32°–38° bright-yellow fruits were produced. Lycopene was developed normally in such fruits when they were returned to temperatures approximating 20°. Chlorophyll decomposition in the fruits proceeded during ripening at temperatures up to a maximum of 40°. Above this temperature, the fruits remained green and did not change color even though subsequently returned to lower temperatures.

Lycopene formation is inhibited by a low oxygen supply, but chlorophyll decomposition is not. Decomposition of the latter during ripening is hastened in the presence of light, but lycopene formation proceeds equally well in either light or darkness, provided other conditions are favorable. Ethylene hastens lycopene formation as well as chlorophyll decomposition and hence has commercial importance in artificial ripening. The relative concentrations and distribution of the various pigments present (lycopene, carotene, xanthophyll, chlorophyll, etc.) determine the color value of various varieties (*28*), and the more intense color of tomatoes imported from Italy is merely associated with relative proportions or distribution of these pigments and not to the presence of other constituents (*77*). The relative amounts of the various pigments in the skin and in the flesh just under the skin are, of course, largely responsible for the color of whole tomatoes. The factors influencing carotene content and its nutritional significance will be discussed later (p. 12).

ASCORBIC ACID

The outstanding value of the tomato in nutrition is due primarily to its vitamin content. Among these vitamins ascorbic acid stands first in importance, considering the amount supplied in relation to human needs. In fact, the production previously cited for the United States contains a potential supply of the vitamin nearly sufficient to meet the entire needs of our population. Of course by no means all of this production reaches the consumer, and further, a part of the supply actually consumed has lost some of its vitamin value due to processing and cooking.

On the average fresh, ripe, summer-grown tomatoes contain about 25 milligrams of ascorbic acid per 100 grams. Thus, one small tomato would supply about one-third of the recommended daily adult allowance of 75 milligrams (*1*). One 4-ounce glass of properly canned tomato juice would supply a similar amount. These figures illustrate the fact that it would be entirely possible to meet the ascorbic acid needs from tomatoes alone. But, of course, the regular daily consumption of the amount required would not be acceptable to the consumer. since this would involve the consumption of three tomatoes, or the equivalent, every day of the year.

Although an average figure has been used above, results in the literature indicate that the ascorbic acid content of whole tomatoes varies considerably, depending upon a number of factors, such as the variety, the location where grown, the season, and the treatment which the fruit received before and after placing them on the market. These results indicate the importance of a consideration of these factors in the production and processing of tomatoes with the objective of providing a supply for consumption that will be less variable and richer in this important vitamin. Thus, in the following pages the present knowledge regarding these factors is reviewed. Unless otherwise noted, the vitamin content is expressed on a fresh-weight basis.

Any discussion of the vitamin content of a particular food must take into consideration the methods used for determining the vitamin values. Because of its importance as a source of vitamin C, considerable study has been devoted to the methods for determining ascorbic acid in tomatoes and tomato products. Fortunately, the tomato seems to be a fruit in which the determination of ascorbic acid by the chemical method is relatively simple.

Several investigators (*22*, *41*, *76*, *99*, and others) have compared the chemical method with the biological assay, using the guinea pig as a means of determining the ascorbic acid in the tomato, and found a close agreement in the results. The method used in practically all of the work discussed here involves the extraction of tomato or tomato juice with a suitable extractant (usually metaphosphoric acid) and subsequent titration of the extract or of an aliquot with standardized 2, 6-dichlorophenol-indophenol. Considering the numerous comparisons of methods, it seems reasonable to assume that most of the work involving the use of the dye titration for comparative studies of ascorbic acid in tomatoes of different sources and different treatments gives dependable results.

Maclinn et al. (*74*, *75*) have reviewed much of the literature up to 1938 on the ascorbic acid content of tomatoes and found reported variations ranging from 5 milligrams to 48 milligrams per 100 grams fresh weight. Numerous other reports suggest that the extreme range in values, which occurs in tomatoes from various sources and at different times of the year, may be from 10 to 50 milligrams ascorbic acid per 100 grams fresh material. These figures should not be interpreted to mean that any such wide ranges are commonly encountered by the consumer. Tomatoes as purchased in the retail market would normally vary as to source and variety in the course of the season, and thus the average ascorbic acid value for the fruit consumed during the course of a week or a month should not be subject to extreme ranges. The possibility of wide departures from the average ascorbic acid content would seem to be greater for rural consumers, where single sources and varieties might well furnish the sole supply to the individual family. In any event, the wide ranges that have been reported for the tomato indicate the need for a thorough understanding of the various factors concerned so as to provide the knowledge that should make possible a food supply of higher nutritional quality.

EFFECT OF HEREDITY

One of the factors that doubtless contributes to the variation in ascorbic acid content is the genetic constitution. Different varieties differ markedly when grown side by side in the same soil. Maclinn et al. (*74, 75*) found variations of from 13 to 44 milligrams per gram of fresh weight in a study of 98 different varieties all grown in the same soil at the same time. Numerous other investigators have found variations correlated with variety. The magnitude of the variations reported by Maclinn and his coworkers seems to be slightly greater than that reported by other workers, but their study was more comprehensive than most. In an investigation of five varieties, Tripp et al. (*130*) found a variation of from 15 to 22 milligrams per 100 grams. Distinctive differences have been found by several others (*8, 37, 114*). On the other hand, Currence (*20*) reported in 1939 that statistically significant differences between varieties were seldom found in field experiments. He emphasized the interrelationship between the given variety and the environmental conditions in determining the ascorbic acid content.

The work of French (*32*) indicated no difference in the ascorbic acid content of so-called red- and pink-fleshed varieties. Biryukov (*8*) crossbred varieties of high and low potencies and found the first generation to have an ascorbic acid content close to the parent with the higher values. Shivrina (*114*) has reported ascorbic acid values as high as 43 milligrams per 100 grams for cultivated varieties, and in some wild varieties values as high as 80 milligrams per 100 grams. He reported that it was possible, by proper selection and breeding, to obtain hybrids high in ascorbic acid. His results indicating differences were all calculated on the fresh-weight basis, but he found the same amount of ascorbic acid in the cultivated as in the wild varieties when the results were calculated on a dry-weight basis. This reported correlation with total solids is not borne out by other work referred to later (*19*). Work, with different varieties of many vegetables other than the tomato, has shown in general a close correlation between variety and ascorbic acid content under the same environmental conditions.

Two reports with respect to the effect of polyploidy on vitamin C content of tomatoes are in contrast to each other. Sansome and Zilva (*106*) worked with tetraploid strains of tomato, which were obtained experimentally from diploid plants. The fruit produced on the tetraploid progeny were compared directly with the diploid parent. In this case they found twice as much ascorbic acid in the juice of the fruit from the tetraploid plant as from the diploid. On the other hand, Key (*58*) worked with tetraploids of unknown origin and compared them with various diploids. She found no appreciable difference in the vitamin C content of the two kinds of fruits.

Attempts have been made to correlate vitamin C content with other conditions of internal environment in fruits that possibly are also influenced by genetic constitution but that, at any rate, are normal to the development of the tomato plant. Thus, the effects of acidity, total solids, sugar content, fruit size, fruit portion, and degree of ripeness have been investigated by a number of workers. Yarbrough and Satterfield (*141*) found no correlation between total acidity and vitamin C. Likewise, Cultrera (*19*) found no definite relationship between acidity, reducing sugars, dry weight, and vitamin C. For certain kinds of fruits, on the other hand, a correlation between acidity and ascorbic acid content has been noted, as is indicated for oranges (*40*, *81*) and for various other fruit juices by Grebinskiĭ (*38*). It is recognized that a high acidity helps protect the vitamin C content of various fruits and vegetables against loss in cooking and canning, and the same apparently applies for storage. Tressler, Mack, and King (*129*) and Tressler (*127*), after a study of a number of vegetables, reported that acid vegetables, such as rhubarb and tomatoes, lost no vitamin C during storage for several days at room temperatures, but that nonacid fruits lost vitamin C rapidly unless refrigerated. Other results (*15*, *74*, *75*) also indicate no loss of vitamin C during storage of ripe tomatoes for at least 1 to 2 weeks at room temperature.

In connection with varietal studies, Tripp et al. (*130*) have studied several varieties of tomatoes growing at the School of Agriculture of the University of North Carolina. They reported the Pritchard variety to have the highest ascorbic acid content of any of those studied (i. e., 22 milligrams per 100 grams of fresh fruit), although the Marglobe was relatively low (16 milligrams per 100 grams of fresh fruit). Reports for these two varieties at other locations (*74*, *75*) usually list the Pritchard variety as one of the least valuable sources of ascorbic acid, whereas the Marglobe is usually the richer one. It may be that these variations are due to the response of the different varieties to the environmental conditions under which they are grown.

Effect of Fruit Development

The size of the fruit within a variety or strain apparently makes little difference with regard to vitamin C content, small fruit containing approximately the same amount per 100 grams fresh weight as do large ones (*15*, *37*, *74*, *75*, *130*, *141*). This is in contrast with pears

(*64*), and apples (*5*), and other fruits in which higher ascorbic acid values for small as compared to large fruits have been reported. In these latter fruits, the ascorbic acid is concentrated near the surface (*126*), and small fruits have more surface per unit volume. With reference to the distribution of ascorbic acid in the fruit, Gomolyako (*37*) found more vitamin C in the flower end of the tomato fruit than in the stem end. Maclinn and Fellers (*74*) found the ascorbic acid most concentrated in the seed area and in the gelatinous substance of the locule, but the outer wall material, because of its relative volume, contributed most of the vitamin C of the fruit.

Some reports (*74*, *75*, *85*) have indicated that the vitamin C content of mature green fruits is essentially the same as for fully ripened ones, and others (*15*, *37*, *50*, *55*, *83*, *87*, *114*, *129*) indicate that ascorbic acid content increases during ripening. As near as can be judged from these reports, it appears that partially grown green tomatoes are poorer in vitamin C than ripe ones, but that after a fruit has reached its full size and is in the so-called mature green stage, the increase in vitamin C during subsequent ripening is relatively slight. Due to the variations that occur from fruit to fruit, this may not be detected with ordinary sampling methods. Certain reports (*114*, *130*) indicate that overripe tomatoes are low in vitamin C.

House, Nelson, and Haber (*50*) and Jones and Nelson (*55*) have reported that ethylene-ripened tomatoes are lower in vitamin C than vine-ripened ones. It has been reported for oranges (*39*) that treatment with ethylene has no effect on the ascorbic acid content.

Effects of Season and Location

Certainly environmental conditions have a marked influence upon the ascorbic acid content. Seasonal variations in fresh fruit have been reported by many investigators (*15*, *20*, *41*, *104*, *129*). Currence (*20*) reports weekly variations associated with environmental conditions. With advancing season, Brown and Moser (*15*) record a slight increase in vitamin C. Sanborn (*104*) noted variations of 100 percent due to growing conditions and variety, which corresponds with the results of Tressler et al. (*129*). Variations in the values of canned juice from year to year were considered by Hanning (*41*) to be correlated more with season than with canning methods. Gomolyako (*37*) and Shivrina (*114*) found marked effects of geographical location. The latter author considered that these effects were correlated with meteorological conditions.

Although the results just reviewed are in general agreement, it is impossible to judge just how much these variations, which occur in the environments where tomatoes are grown commercially, affect the ascorbic acid values of market tomatoes. If, as seems possible, the location where plants are grown is just as important, or more so, in determining the ascorbic acid values of the fruits as is the variety, then the following two conclusions may be drawn: (1) The assigning of ascorbic acid values to various varieties must be correlated with location; and (2) the selection of varieties high in ascorbic acid must be carried out in many locations, since the richest in vitamin C in one location might be relatively inferior in another (see previous discussion (p. 7) of work of Tripp et al. (*130*)). The results, obtained with other kinds of fruits, serve to support the evidence with tomatoes that location where grown and season are important in determining the vitamin C content.

Varietal differences in vitamin C content of most vegetables do seem to exist, but differences caused by various environmental factors modify the expression of this particular varietal characteristic (*102*). In this regard, however, as in many others in the field of vitamin literature, contradictions may be found. Thus one report from Florida (*33*) indicates that variations that occurred in oranges were not correlated with locations in which they were grown; while another from Texas (*80*) finds grapefruit and oranges vary more because of the location in which they are grown than because of the variety. The former report found wide variation among varieties and also in the same variety, although for an individual tree the ascorbic acid values tend to be fairly uniform. It was also found (*40*) that in the same variety of South African oranges the ascorbic acid content varied considerably within an individual grove, and varied greatly from one grove to another. In Germany it has been reported (*57*) that a given variety of apples contained more vitamin C in the southern than in the northern section of the country. According to Krusser (*64*) the same varieties of pears grown in different regions differ in vitamin C content, but this may be due to differences in soils, fertilizers, and other conditions of growth. With various vegetables and fruits (*16*, *43*, *71*, *79*, *88*, *129*, *142*) considerable effects of season on the ascorbic acid content have been observed. In grapefruit and oranges the ascorbic acid content is low at the end of the season, according to Metcalfe et al. (*80*). It has been reported (*73*) that early varieties of snap beans are richest in the vitamin. An interesting study (*9*) of several varieties of plants, including cabbage, radish, and potato, reports increases in ascorbic acid content with an increase in altitude.

EFFECTS OF NUTRITION

There are some indications that soil type and cultural practice influence ascorbic acid content. Hester and Kohman (*48*) claimed a correlation between the vitamin C content of tomatoes and the soil type upon which they were grown, but since the various soil types were in different locations, it seems possible that some of their differences may have been due to factors other than soil. Hester (*46*) found that application of potassium fertilizer to certain soils resulted in an increase in the yield and vitamin C content of tomato fruits and that (*47*) on soils deficient in manganese the application of manganese produced a similar effect. French (*32*) grew vegetables in nutrient solution and found no effect of potassium or phosphorus deficiencies, provided the nitrogen supply was ample. In certain studies with other plants (*72*, *110*, *137*, *138*), little effect due to fertilization practices has been noted. On the other hand, it has been reported for apples (*57*) that excess nitrogen fertilization decreases ascorbic acid. With Swiss chard (*53*) a high nitrogen supply has been reported to increase ascorbic acid content, but no such effect was noted with spinach.

EFFECTS OF LIGHT

One of the environmental factors playing a part in seasonal fluctuations and perhaps in locational differences is doubtless light intensity. Veselkine et al. (*134*) produced tomato fruits in double sacks of black paper, which excluded light. Such fruits were smaller than fruits produced under normal illumination, contained no yellow pigment in the epidermis, and were entirely white on the surface. The interior was a light red, indicating a small amount of lycopene. These tomatoes contained about one-fifth the ascorbic acid content per unit fresh weight of fruit produced in light and weighed about one-third as much. This is in accord with results which indicate that tomatoes grown in the greenhouse have about one-half the ascorbic acid content of those grown out of doors (*15*), and that fruits from unsupported vines are lower in vitamin C than those from pole-supported vines (*15*). Kohman and Porter (*62*) found that the ascorbic acid content of the vegetative parts of the tomato plant decreased markedly when the plants were moved from direct sunshine to diffused daylight and increased again when they were returned to sunshine. On the other hand, Currence (*20*) found that weekly differences in vitamin C in the fruit appeared to have little relation to the percentage of sunshine.

Specific data in relation to light conditions are relatively few for tomatoes, but the findings are generally in agreement with the more extensive results with other plants. Numerous investigations (*70*, *78*, *122*, *133*) have shown that etiolated seedlings (i. e., those germinated in darkness or grown in a light of low intensity) are considerably lower in ascorbic acid content than seedlings grown in the light, and some have interpreted this to indicate a connection with chlorophyll synthesis. Veselkine et al. (*133*), however, reported that the synthesis of vitamin C under the action of light seemed to be independent of the synthesis of chlorophyll. Sugawara (*123*) thought that red light induced synthesis of ascorbic acid more readily than light of any other quality except white, and that blue light was the least effective. Yet Tsuge and Kurihara (*131*) reported the synthesis to be accelerated by ultraviolet radiation. On the other hand, Virtanen and Eerola (*135*) reported little effect of light on formation during the germination of peas but indicated the importance of temperature. Reid and Weintraub (*95*) found that roots cultured in the presence of light had four to ten times the quantity of those cultured in darkness. They attributed the increase in ascorbic acid to the presence of well-developed chloroplasts. Reports given for pears, persimmons, and oranges by Mituda (*82*) indicate that the amount present is proportional to the amount of sunlight received during ripening. Harding and Winston (*42*) found a higher content in oranges picked from the outside branches where they were well exposed to sunlight.

Numerous investigations (*5*, *57*, *64*, *86*, *139*) have indicated that in several fruits the ascorbic acid is concentrated in or near the skin, which may indicate a light relationship. There seems to be more on the sunny side of fruits than on the shaded side (*57*, *86*). These facts led Watanabe (*139*) to suggest that vitamin C is synthesized in the skin under the action of light and transported inward. In agreement with the above investigations with fruits, it has been reported (*98*) that the outer leaves of cabbage, which are exposed to sunlight, show a higher content and that the outside leaves of head lettuce have more than the inside leaves (*109*).

Although the reports on the effect of light on ascorbic acid content are somewhat contradictory, the numerous studies with the various plants discussed indicate that light intensity does have an effect. Doubtless the effects of light are interrelated with the temperature effects, and the two factors are hard to separate. From the available data it seems probable that these two factors, temperature and light, are in conjunction with varietal differences, the most important factors influencing vitamin C potency. Subsequent work with the microelements, particularly manganese, may demonstrate the importance of the availability of these minerals.

All of the results previously discussed indicate that the ascorbic acid content of tomato fruits is dependent largely on the variety, on the location where grown, and on seasonal conditions. Although the results are inconclusive, it appears that the cultural practices (except those involving exposure to light and possibly supply of microelements) are of relatively slight importance and that harvesting methods (i. e., whether or not the fruit is picked mature green or vine ripe) also are relatively unimportant. Nevertheless, the numerous results indicate that all of the variations that are known to occur are not due simply to variety. Therefore, the conclusion seems logical that next to variety the meteorological conditions are of prime importance in determining the ascorbic acid content of tomato fruit. Little is known concerning the effects of the supply of microelements, but these may also be of great importance. Clearly, further work relative to these factors is needed to provide the knowledge necessary for recommending crop practice in a given locality.

PROCESSED TOMATO PRODUCTS

Numerous investigators have followed the variations in ascorbic acid content of tomatoes during the canning process and the production of juices and other products. No attempt will be made to review this literature in detail. Details may be found in the original work.

If proper precautions are taken little loss of ascorbic acid occurs during processing (*18, 21, 30, 60, 68, 130*). The desirability of avoiding any treatment that permits oxidation is emphasized (*26, 51, 61, 104*). Prolonged heating may be detrimental (*12, 26, 52, 60*), and the use of rustproof equipment throughout has been recommended (*68*). Several investigators have compared products preserved in glass jars or bottles with those in cans. Some data (*23, 44, 51*) indicate a greater loss in ascorbic acid when the material is placed in glass containers as compared with tins. Others (*68, 128*) have reported that this excessive loss in glass containers does not occur if they are completely filled. Reynolds (*96*) claimed that metallic tin had a protective effect by adding the metal to juice in glass jars, and Hussemann (*51*) reports that metal caps on bottles give more effective preservation than paraffined corks. Inagaki (*52*) reported that sealing the juice in cans with varnish linings resulted in considerable loss. The desirability of preventing certain metal contaminations (especially iron and copper) during processing has been emphasized (*31, 54, 65, 97, 140*).

Reports of loss of the vitamin during long periods of storage in cans vary from approximately 10 percent (*130*) up to 25 percent or more (*23, 51*). Hauck (*44*) found that tomato juice in tin cans lost one-fourth of its ascorbic acid when held in the refrigerator for 4 days after opening. Other reports (*2, 74, 120*) contain additional information on the preservation of ascorbic acid during processing.

In the process of stewing tomatoes, Das and Biswas (*24*) reported an increased loss of ascorbic acid with the addition of water. Ascorbic acid in protein-free tomato juice obtained by the removal of material coagulated at 70° C. was very sensitive to destruction by heat. Emanuele (*26*) gives figures for the destruction of the vitamin in air during cooking at different temperatures for different lengths of time and over various pH ranges. He recommends a cooking temperature of 70° C. Bolcato (*12*) reported less loss of vitamin C in the preparation of tomato concentrates by heating at 60°–70° than by heating at temperatures either higher or lower. Inagaki (*52*) reported the presence of an ascorbic acid oxidizing enzyme in tomato juice, whose action was completely checked by heat at 65° for 10 minutes.

Kardo-Syssoyeva and Nissenbaum (*56*) report a substance present in fresh tomatoes that stabilized vitamin C against oxidation. This substance occurred chiefly within the tissues and was only partially removed in solution. It was completely destroyed by boiling in solution but was only partially inactivated by boiling in the tissues. Naito and Isimaru (*87*) report only a trace of combined ascorbic acid in unripe tomatoes. They found that the amount of ascorbic acid oxidase decreases in the fruit during ripening.

It is evident from this literature on canned tomato products that a good deal of the ascorbic acid may be lost during the processing unless care is exercised, but that most of the vitamin potency may be preserved if suitable precautions are taken. Tomatoes lend themselves to the production of juice high in ascorbic acid more readily than many other fruits, but the importance of proper processing methods is obvious. It is also clear from the literature previously reviewed that an important factor in improving the vitamin C potency of commercial products would be to utilize fruits in the canning process that are initially rich. Until more is known concerning the relationship between variety and environment, no definite statement can be made concerning the best varieties to be used in the different locations for this purpose.

CAROTENE

According to Munsell (*85*) fresh, ripe tomatoes or juice contain 1,000 International units of vitamin A per 100 grams, on the average. Booher, Hartzler, and Marsh[5] give a figure of 1,150 International units per gram. On the basis of these figures, a small tomato or glass of juice would supply 20 percent or more of the recommended daily adult allowance of 5,000 International units (*1*). It is therefore clear that the tomato could make a very important contribution to the vitamin A requirement of the human diet.

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[5] BOOHER, L. E. HARTZLER, E. R., and MARSH, R. L. A TABLE OF THE VITAMIN CONTENT OF FOODS. [Mimeographed table prepared by the Bureau of Home Economics, U. S. Dept. Agr., October 1940.]

The published data indicate that the carotene content of tomatoes, like that of vitamin C, is subject to wide variation. It is apparent, however, that many of these variations are associated with the methods of determining the values, whether chemical or biological, and with the methods of translating these values into International units.

Although the absolute values reported by various investigators may not be entirely comparable owing to the different methods used, the studies of several individual workers have provided relative figures for vitamin A or carotene (provitamin A) that reveal variations according to degree of ripeness, variety, exposure to light, and so on. Many reports (*50*, *55*, *59*, *84*, *114*, *116*, *119*) are in agreement that vitamin A potency or carotene content of tomatoes increases during ripening. Some reports (*50*, *55*) indicate that vine-ripened fruits are more potent sources than fruits detached while partially green and ripened in air or ethylene, although ripe fruits are richer than green fruits regardless of method of ripening. Morgan and Smith (*84*), however, report ethylene- or air-ripened fruits equivalent to vine-ripened fruits in vitamin A potency. According to an abstract of the work of Kirsanova (*59*), overripe tomatoes stored in the dark at room temperatures had an initial concentration of carotene of 5.6 milligrams per 100 grams which increased to 8.9 milligrams up to the fifth day, after which the content decreased to 4.9 milligrams on the twelfth day. Green tomatoes increased from 1.7 milligrams to a maximum of 7.16 milligrams on the twelfth day. The work of this investigator suggests that the carotene content may vary several hundred percent due to stage of ripeness.

The vitamin A potency also varies markedly with variety (*90*, *114*, *115*), red varieties being much more potent than so-called pink or white varieties, in contrast to the data for vitamin C previously discussed (p. 6).

Smith (*119*) studied the effects of light on carotenoid formation in tomato fruits. Using the Bonny Best variety he found that greenhouse-grown tomatoes did not contain so large a quantity of carotenoid pigments as did fruits produced out-of-doors. Fruits ripened on the vine in darkness, after initial development had occurred in the light, contained less of the carotenoids than did fruits ripened in the light. The maximum content was attained in full exposure to light on the vine. Exposure to wave lengths, approximating 5,400 to 5,800, did not result in so much carotenoid production as did some of the longer and shorter wave lengths. Low light intensities favored lycopene formation.

Scheunert and Wagner (*111*) found the vitamin A value affected little by fertilization, except under conditions of extreme depletion of mineral supply. They found an average of approximately 1,600 International units per 100 grams fresh material under the most varied conditions of origin and season.

Fellers (*29*) reports that the carotene in vegetables is stable to heat and cold and not ordinarily affected by the canning processes. This is in agreement with several reports (*18*, *25*, *61*) that canned tomatoes and tomato juices have vitamin A potencies equal to the fresh material. Poe et al. (*94*) found no marked differences in the vitamin A potency of 15 brands of commercially canned tomato juice. Prolonged heating accompanied by exposure to air results in some destruction of vitamin A potency (*29*) and thus concentrates (*25*) may be somewhat low. Most of the vitamin A value is present in the solid matter, and thus filtered tomato juices are very low in it (*34*, *61*, *94*). Dried tomato pomace is a fair source of vitamin A (*27*).

The above results for vitamin A potency of tomatoes and tomato products indicate that marked variations occur, depending principally upon variety and stage of ripeness. Environmental conditions, such as exposure to light, are also of importance. From a practical standpoint the stage of ripeness is not an important consideration here because tomatoes are usually canned or consumed only when ripe and because the method of ripening seems to have little effect. Environmental conditions associated with production during the winter season may have considerable significance, as greenhouse-grown tomatoes are of importance commercially and as results indicate that such tomatoes are low in value (*119*). From the standpoint of improving the vitamin A potency of tomatoes, the utilization of fully ripened fruit of the proper varieties appears the most promising procedure.

OTHER VITAMINS

Various other vitamins are present in tomatoes, but in contrast to ascorbic acid and carotene, the amounts are small in terms of human needs. Roscoe (*101*) and Plimmer and associates (*93*) early reported that the potency of vitamin B_1 in the tomato was only a small fraction of that in yeast. Later Baker and Wright (*4*) reported a value of 40 International units per 100 grams in tomato pulp. Munsell (*85*) gives a value of 23 International units for green tomatoes, 25 for ripe fruit, and 25 for the juice. Other recent reports list similar values. On this basis a small tomato contains only about one twenty-fifth of the recommended daily allowance for the adult man (*1*).

Cultrera (*18*) reported that fresh tomatoes, tomato juice, tomato paste, and tomato extract were all about equally rich in vitamin B_1. Veselkine et al. (*134*) allowed tomatoes to develop in complete darkness after they had become established on the vine under exposure to light. They found that such fruits, although they weighed about one-third as much as comparable fruits grown in light, nevertheless had slightly more vitamin B_1. They also found the synthesis of vitamin B_1 to be independent of the synthesis of vitamin C. However, Jones and Nelson (*55*) observed that mature green, full-grown tomatoes are equivalent to immature ones in vitamin B_1 and contain less than vine-ripe fruit. De Caro and Perling (*25*) reported that the vitamin B content was reduced about half during the canning process. The studies reported in this paragraph were all made prior to 1935.

Early studies indicated the riboflavin content of tomatoes to be rather low. A recent study by Hodson (*49*) using the fluorometric method reported a value of 52 micrograms per 100 grams, which was a lower figure than he found for apples, pears, or peaches. Using the rat assay method in a later study, Lanford et al. (*66*) found a value of 37.3 micrograms per 100 grams, which was higher than the value they obtained for either apples or pears. On the basis of these values it is evident that the tomato makes a very small contribution to the recommended riboflavin allowance for the adult of 2,700 micrograms (*1*).

The early work by Goldberger and associates (*35*, *36*) showed that tomatoes had a definite but feeble pellagra-preventive action. According to a review by Bacharach (*3*) the tomato contains less than 0.5 milligrams of nicotinic acid per 100 grams. It is evident that further studies are needed. It appears, however, considering the human requirement as 18 milligrams (*1*), that the tomato, in the amount commonly consumed, does not make a large contribution to the diet in terms of the need for this factor.

There appear to be no reliable data regarding the amounts of the other factors in the B complex that may be in the tomato.

In 1931 Steenbock and Schrader (*121*) reported that the vitamin D content of tomatoes was negligible. This has been confirmed by Tisdall et al. (*125*) and by Piegai (*92*).

MINERAL CONTENT

The literature contains hundreds of papers dealing with variations in the mineral content of tomatoes as influenced by various factors. No detailed review of these data are presented, however, because tomatoes at their best, in the amounts commonly consumed, do not make any very significant contribution of those minerals in which the diet is likely to be lacking. A few individual reports are cited and reference is made to the comprehensive review by Beeson (*7*), who has discussed the factors affecting the mineral content of many plants. The following figures have been taken bodily from his tables and are percentages on a moisture-free basis. The average of 58 analyses on the calcium content of tomato fruit was 0.24 percent, and the variations that occurred were from 0.08 to 0.48 percent. The phosphorus content in 62 analyses varied from 0.29 to 0.84 percent, with an average of 0.55. Although these variations are impressive, it is evident, even considering the highest values that might be expected in 100 grams of fresh tomato (i. e., approximately 33 milligrams of calcium and 58 milligrams of phosphorus), that the usual consumption of tomato would not contribute materially to the daily human need (approximately 800 milligrams of calcium and 1,300 milligrams of phosphorus).

The data for 82 iron analyses as compiled by Beeson revealed a range from 48 to 800 p. p. m. on an air-dry basis. About 65 percent of all the analyses were within the range of 103 to 270 p. p. m., with a mean value of 155. This value is equivalent to approximately 12 p. p. m. of fresh material. Other compilations have given lower values. For example, Sherman (*113*) gives a percentage value equivalent to 6 p. p. m. It is evident that further studies are needed to ascertain to what extent the wide variations found in the reported figures are due to specific environmental factors and to what extent they may be due to analytical errors.

A number of reports have dealt with the presence of copper in tomatoes and tomato products. Fruits produced on various types of soils in different locations vary considerably in the amount of this element present. Several citations (*7*, *112*, *140*) indicate that the amount of copper will vary from 5 to 25 p. p. m. on the dry-weight basis, or a variation of approximately 0.35 to 2.5 p. p. m. on the fresh-weight basis. The accumulation of copper during the processing of tomato products through the use of copper utensils has been discussed in several reports (*45*, *54*, *65*, *67*, *89*, *91*, *103*). This accumulation should be avoided, because of its destructive effect on vitamin C (*63*, *76*).

LITERATURE CITED

(1) Anonymous.
1941. RECOMMENDED DIETARY ALLOWANCES. Natl. Res. Council Committee on Food and Nutr. [5] pp. [Washington, D. C.]

(2) Abbott, O. D.
1939. STANDARDIZATION OF HOME-CANNED TOMATOES AND TOMATO JUICE. Fla. Agr. Expt. Sta. Ann. Rpt. 1939: 101.

(3) Bacharach, A. L.
1941. THE DISTRIBUTION OF NICOTINIC ACID IN HUMAN AND ANIMAL FOODS. Nutr. Abs. and Rev. 10: 459–465.

(4) Baker, A. Z., and Wright, M. D.
1935. THE VITAMIN B_1 CONTENT OF FOODS. Biochem. Jour. 29: 1802–1807, illus.

(5) Batchelder, E. L., and Overholser, E. L.
1936. FACTORS AFFECTING THE VITAMIN C CONTENT OF APPLES. Jour. Agr. Res. 53: 547–551.

(6) Beadle, N. C. W.
1937. STUDIES IN THE GROWTH AND RESPIRATION OF TOMATO FRUITS AND THEIR RELATIONSHIP TO CARBOHYDRATE CONTENT. Austral. Jour. Expt. Biol. and Med. Sci. 15: 173–189, illus.

(7) Beeson, K. C.
1941. THE MINERAL COMPOSITION OF CROPS WITH PARTICULAR REFERENCE TO THE SOILS IN WHICH THEY WERE GROWN. U. S. Dept. Agr. Misc. Pub. 369, 164 pp., illus.

(8) Biryukov, D.
1938. [VITAMIN C IN TOMATOES AND IN PEPPER.] Konserv. Prom. 4: 18–19. [Chem. Abs. 33: 9364. 1939.]

(9) Blagoveshchenskii, A. V.
1937. THE INFLUENCE OF THE CONDITIONS OF GROWTH ON THE VITAMIN C CONTENT OF CERTAIN PLANTS. Bul. Biol. Med. Expt. U. S. S. R. 3: 189–190.

(10) Bohart, G. S.
1939. STUDIES ON THE ACIDITY OF WESTERN (GROWN) TOMATOES. West. Canner and Packer (29th Yearbook) 31: 77. [Chem. Abs. 34: 135. 1940.]

(11) ———
1940. STUDIES OF WESTERN TOMATOES. Food Res. 5: 469–486, illus.

(12) Bolcato, V.
1936. [THE PREPARATION OF CONCENTRATED TOMATO EXTRACTS IN RELATION TO THE KEEPING QUALITIES OF VITAMIN C. I. EXPERIMENTS ON THE JUICES.] Indus. Ital. delle Conserve Aliment. 11: [89]–92, illus. [Chem. Abs. 31: 1909. 1937.]

(13) Borntraeger, A.
1932. ENTHALTEN DIE TOMATEN FRÜCHTE OXAL UND GLYKOLSÄURE? Ztschr. f. Untersuch. der Lebensmtl. 63: 447–448. [Nutr. Abs. and Rev. 2: 245. 1932.]

(14) Brass, K., Beyrodt, A., and Mattausch, J.
1937. ÜBER DIE PIGMENTE DES GELBEN PARADIESAPFELS. Naturwissenshaften 25: 60–61.

(15) Brown, A. P., and Moser, F.
1941. VITAMIN C CONTENT OF TOMATOES. Food Res. 6: 45–55.

(16) Bukin, V. N.
1937. NORTHERN APPLE VARIETIES AS A SOURCE OF VITAMIN C. Bul. Appl. Bot., Genet., and Plant Breeding, Sup. 84, Vitamin Prob. 2: 175–182. [English summary *in* Summaries, p. 7.]

(17) Chevalier, M. G., and Suisse, J.
1937. LA MATURITÉ DES TOMATES. Ann. des Falsif. 30: 350–355, illus.
(18) Cultrera, R.
1933. SUL CONTENUTO VITAMINICO DEL POMODORO E DEI PRODOTTI DERIVATI IN CONSERVA. Indus. Ital. delle Conserve Aliment. 8: [53]–72, illus.
(19) ———
1935. SUL CONTENUTO IN ACIDO ASCORBICO DEL POMODORO. Indus. Ital. delle Conserve Aliment. 10: [1]–4. [Nutr. Abs. and Rev. 5: 379. 1935.]
(20) Currence, T. M.
1940. A COMPARISON OF TOMATO VARIETIES FOR VITAMIN C CONTENT. Amer. Soc. Hort. Sci. Proc. (1939) 37: 901–904.
(21) Daggs, R. G., and Eaton, A. G.
1934. VITAMIN C CONTENT OF CANNED TOMATO JUICE. Indus. and Engin. Chem., Indus. Ed., 26: 292–295, illus.
(22) Daniel, E. P., Kennedy, M. H., and Munsell, H. E.
1936. RELATIVE VITAMIN C CONTENT OF ORANGE AND TOMATO JUICES DETERMINED CHEMICALLY AND BIOLOGICALLY. Jour. Home Econ. 28: 470–474.
(23) ——— and Rutherford, M. B.
1936. EFFECT OF HOME CANNING AND STORAGE ON ASCORBIC ACID CONTENT OF TOMATOES. Food Res. 1: 341–347.
(24) Das, K. L., and Biswas, H. G.
1938. INVESTIGATIONS OF VITAMIN 'C' IN RIPE TOMATO JUICE. Sci. and Cult. 4: 250–252. [Chem. Abs. 33: 1053. 1939.]
(25) De Caro, L., and Perling, G.
1936. [VITAMIN A, B AND C CONTENT OF TOMATO CONSERVES.] Quaderni della Nutr. 3: [64]–81, illus. [Nutr. Abs. and Rev. 6: 57. 1936.]
(26) Emanuele, E.
1937. RECENT ITALIAN RESEARCH UPON THE NUTRITIVE VALUE OF CANNED FOODS. Food 7: 50. [Chem. Abs. 32: 1799. 1938.]
(27) Esselen, W. B., Jr., and Fellers, C. R.
1939. THE NUTRITIVE VALUE OF DRIED TOMATO POMACE. Poultry Sci. 18: 45–47.
(28) Euler, H. von, Karrer, P., Krauss, E. von, and Walker, O.
1931. ZUR BIOCHEMIE DER TOMATENFARBSTOFFE. Helvetica Chim. Acta 14: 154–162. [Nutr. Abs. and Rev. 1: 428. 1932.]
(29) Fellers, C. R.
1940. EFFECT OF PROCESSING ON THE VITAMIN A (CAROTENE) CONTENT OF FOODS. Inst. Food Tech. Proc. 1: 97–107.
(30) ——— Clague, J. A., and Isham, P. D.
1935. VALUE OF COMMERCIALLY CANNED AND LABORATORY-PREPARED TOMATO JUICES AS ANTISCORBUTICS. Jour. Home Econ. 27: 447–451.
(31) Fomin, S., and Makarowa, P.
1936. [ANTISCORBUTIC VALUE OF TOMATOES TREATED BY DIFFERENT TECHNICAL METHODS.] Ukrain. Biokhem. Zhur. 9: [387]–394. [German summary, pp. 393–394.]
(32) French, R. B.
1939. THE INVESTIGATION OF VITAMIN C CONTENT OF FLORIDA FRUITS AND VEGETABLES. Fla. Agr. Expt. Sta. Ann. Rpt. 1939: 85.
(33) ——— and Abbott, O. D.
1940. INVESTIGATION OF THE VITAMIN C CONTENT OF FLORIDA FRUITS AND VEGETABLES.—I. EFFECTS OF MATURATION AND OF COLD STORAGE ON THE VITAMIN C POTENCY OF ORANGES AND GRAPEFRUIT. Jour. Nutr. 19: 223–232, illus.
(34) Gant, O. K.
1935. THE VITAMIN A CONTENT OF COMMERCIALLY CANNED TOMATO JUICE AND THE VITAMIN G CONTENT OF CELERY. (Abstract of thesis) Colo. Univ. Studies 23: 21–22. [Abstract in Expt. Sta. Rec. 74: 885. 1936.]
(35) Goldberger, J., and Wheeler, G. A.
1927. A STUDY OF THE PELLAGRA-PREVENTIVE ACTION OF THE TOMATO, CARROT, AND RUTABAGA TURNIP. U. S. Pub. Health Serv. Rpts. (Reprint No. 1157) 42: 1299–1306.

(36) Goldberger, J., Wheeler, G. A., Lillie, R. D., and Rogers, L. M.
1928. A STUDY OF THE BLACKTONGUE-PREVENTIVE ACTION OF 16 FOODSTUFFS, WITH SPECIAL REFERENCE TO THE IDENTITY OF BLACKTONGUE OF DOGS AND PELLAGRA OF MAN. U. S. Pub. Health Serv. Rpts. 43: 1385–1454.

(37) Gomolyako, L. G.
1937. VARIABILITY IN THE AMOUNT OF ANTI-SCORBUTIC VITAMIN IN DIFFERENT TOMATO VARIETIES. Bul. Appl. Bot., Genet., and Plant Breeding, Sup. 84, Vitamin Prob. 2: 116–128. [English summary *in* Summaries, p. 5.]

(38) Grebinskiĭ, S. O.
1940. RIPENING PROCESS IN SEPARATE PARTS OF THE FRUIT. Acad. Sci. U. R. S. S. Compt. Rend. 26: 264–266. [Chem. Abs. 34: 5879. 1940.]

(39) ———
1940. THE ACCUMULATION AND TRANSFORMATION OF SUBSTANCES DURING RIPENING AND STORING OF CITRUS FRUITS. Biokhim. Kul'turnykh Rast. 7: 276–300. [Chem. Abs. 35: 2927. 1941.]

(40) Hamersma, P. J.
1938. THE VITAMIN C CONTENT OF SOUTH AFRICAN ORANGES AND ITS STABILITY OVER STORAGE PERIODS, SOME EXCEEDING THREE MONTHS, AT APPROXIMATELY 38° F. Union So. Africa Dept. Agr. Forestry Sci. Bul. 163. 53 pp. [Chem. Abs. 32: 5522. 1938.]

(41) Hanning, F.
1936. COMPARISON OF THE BIOLOGICAL AND CHEMICAL METHODS FOR THE DETERMINATION OF VITAMIN C IN CANNED STRAINED VEGETABLES AND A STUDY OF ITS VARIATION FROM YEAR TO YEAR. Jour. Nutr. 12: 405–412.

(42) Harding, P. L., and Winston, J. R.
1939. THE ASCORBIC ACID (VITAMIN C) CONTENT OF JUICE OF THE PRINCIPAL VARIETIES OF FLORIDA ORANGES. Fla. State Hort. Soc. Proc. 52: 90–95. [Chem. Abs. 34: 3389. 1940.]

(43) ——— Winston, J. R., and Fisher, D. F.
1939. SEASONAL CHANGES IN THE ASCORBIC ACID CONTENT OF JUICE OF FLORIDA ORANGES. Amer. Soc. Hort. Sci. Proc. (1938) 36: 358–370.

(44) Hauck, H. M.
1938. VITAMIN C CONTENT OF HOME-CANNED TOMATO JUICE. Jour. Home Econ. 30: 183–188.

(45) Herd, M.
1939. THE PROPORTION OF COPPER IN TOMATO PUREÉ. Analyst 64: 346–347.

(46) Hester, J. B.
1940. THE INFLUENCE OF POTASH FERTILIZATION UPON THE YIELD AND QUALITY OF TOMATOES. Amer. Fert. 93 (11): 5–9, 24, 26, illus.

(47) ———
1941. MANGANESE AND VITAMIN C. Science 93: 401.

(48) ——— and Kohman, E. F.
1940. THE INFLUENCE OF SOIL TYPE AND FERTILIZATION UPON THE YIELD AND COMPOSITION OF TOMATOES. Soil Sci. Soc. Amer. Proc. 5: 281–283.

(49) Hodson, A. Z.
1940. RIBOFLAVIN CONTENT OF SOME COMMON VEGETABLES AND FRUITS. Food Res. 5: 395–398.

(50) House, M. C., Nelson, P. M., and Haber, E. S.
1929. THE VITAMIN A, B AND C CONTENT OF ARTIFICIALLY VERSUS NATURALLY RIPENED TOMATOES. Jour. Biol. Chem. 81: 495–504, illus.

(51) Hussemann, D. L.
1935. VITAMIN C IN HOME CANNED TOMATO JUICE. Wis. Agr. Expt. Sta. Ann. Rpt. 1933–34 (Bul. 430): 135, 136.

(52) Inagaki, T.
1939. STUDIES ON VITAMIN C IN FRUIT JUICE PRODUCTS. I. INFLUENCES OF THE PROCESS OF PREPARING CANNED TOMATO JUICE ON THE VITAMIN C CONTENT. Agr. Chem. Soc. Japan Jour. 15: 903–914. [Chem. Abs. 34: 537. 1940.]

(53) Isgur, B., and Fellers, C. R.
1937. A PRELIMINARY STUDY OF THE RELATIONSHIP BETWEEN VITAMIN C CONTENT AND INCREASED GROWTH RESULTING FROM FERTILIZER APPLICATIONS. Jour. Amer. Soc. Agron. 29: 890–893.

(54) Janson, J. T., and Allen, C. E.
1940. METALLIC CONTAMINATION OF FOODS. Canad. Chem. and Process Indus. 24: 389–391, 394. [Chem. Abs. 34: 6715. 1940.]

(55) Jones, D. B., and Nelson, E. M.
1930. VITAMIN CONTENT OF ETHYLENE-TREATED AND UNTREATED TOMATOES. Amer. Jour. Pub. Health. 20: 387–394, illus.

(56) Kardo-Syssoyeva, E. K., and Nissenbaum, R. F.
1938. [THE FATE OF VITAMIN C IN TOMATOES.] Biokhimii͡a 3: 348–354. [English summary, p. 354.] [Nutr. Abs. and Rev. 8: 657. 1939.]

(57) Kessler, W.
1939. ÜBER DEN VITAMIN C-GEHALT DEUTSCHER APFELSORTEN UND SEINE ABHÄNGIGKEIT VON HERKUNFT, LICHTGENUSS, DÜNGUNG, DICHTE DES BEHANGES UND LAGERUNG. Gartenbauwissenschaft 13: [619]–638, illus.

(58) Key, K. M.
1933. THE DETERMINATION OF VITAMIN C IN DIPLOID AND TETRAPLOID TOMATOES. Biochem. Jour. 27: 153–156.

(59) Kirsanova, V. A.
1938. [CHANGES IN THE CAROTENE CONTENT DURING THE RIPENING AND OVERRIPENING OF "BEST-OF-ALL" TOMATOES.] Voprosy Pitaniya 7 (4–5): 45–46. [Chem. Abs. 33: 4690. 1939.]

(60) Kohman, E. F., Eddy, W. H., and Gurin, C. Z.
1933. VITAMINS IN CANNED FOODS.—XIII. CANNING TOMATO JUICE WITHOUT VITAMIN C LOSS. Indus. and Engin. Chem. 25: 682–684, illus.

(61) ——— Eddy, W. H., and Zall, C.
1930. VITAMINS IN CANNED FOODS.—IX. TOMATO PRODUCTS. Indus. and Engin. Chem. 22: 1015–1017, illus.

(62) ——— and Porter, D. R.
1940. SOLAR RAYS AND VITAMIN C. Science 92: 561, illus.

(63) Kroker, F.
1938. DER EINFLUSS DES KOCHENS, DER HITZEKONSERVIERUNG UND DER TROCKNUNG AUF DEN VITAMINGEHALT VON OBST-UND GEMÜSE. Forschungsdienst 6: 107–129.

(64) Krusser, O. V.
1940. THE DEPENDENCE OF THE CHEMICAL COMPOSITION OF PEARS ON GEOGRAPHICAL FACTORS. Biokhim. Kul'turnykh. Rast. 7: 78–84. THE DYNAMICS OF THE TRANSFORMATION OF SUBSTANCES DURING RIPENING AND STORING OF PEARS. 7: 84–94. CHEMICAL DIFFERENCES OF DIFFERENT VARIETIES OF PEARS. 7: 94–99. [Chem. Abs. 35: 2561. 1941.]

(65) Lamb, F. C., and Lloyd, P. R.
1939. COPPER CONTENT OF TOMATOES AND TOMATO PRODUCTS. West. Canner and Packer (29th Yearbook) 31(5): 77–78. [Chem. Abs. 34: 186. 1940.]

(66) Lanford, C. S., Finkelstein, B., and Sherman, H. C.
1941. RIBOFLAVIN CONTENTS OF SOME TYPICAL FRUITS. Jour. Nutr. 21: 175–177.

(67) La Parola, G., and Bucci, F.
1940. [PRESENCE AND DETERMINATION OF COPPER IN PRESERVED TOMATOES.] Ann. di Chim. Appl. [Rome] 30: [99]–116, illus.

(68) Lebedev, A.
1938. [THE PRESENCE OF VITAMIN C IN CANNED FRUITS AND VEGETABLES.] Konserv. Prom. (2): 18–21. [Chem. Abs. 33: 7915. 1939.]

(69) Lee, F. A., and Sayre, C. B.
1940. EFFECT OF SOIL MOISTURE ON ACID CONTENT OF TOMATOES. Food Res. 5: 69–72.

(70) Lee, W. Y., and Read, B. E.
1936. THE EFFECT OF LIGHT ON THE PRODUCTION AND DISTRIBUTION OF ASCORBIC ACID IN GERMINATED SOYBEANS. Chinese Chem. Soc. Jour. 4: 208–218, illus.

(71) Lojander, W.
1940. [SEASONAL VARIATION IN THE VITAMIN C CONTENT OF THE MOST COMMON VEGETABLES.] Nord. Med. 5: 199–201. [Chem. Abs. 34: 3390. 1940.]

(72) Lyons, M. E., and Fellers, C. R.
1939. POTATOES AS CARRIERS OF VITAMIN C. Amer. Potato Jour. 16: 169–179.

(73) Mack, G. L., Tapley, W. T., and King, C. G.
1939. VITAMIN C IN VEGETABLES.—X, SNAP BEANS. Food Res. 4: 309–316.

(74) Maclinn, W. A., and Fellers, C. R.
1938. ASCORBIC ACID (VITAMIN C) IN TOMATOES AND TOMATO PRODUCTS. Mass. Agr. Expt. Sta. Bul. 354, 39 pp., illus.

(75) ——— Fellers, C. R., and Buck, R. E.
1937. TOMATO VARIETY AND STRAIN DIFFERENCES IN ASCORBIC ACID (VITAMIN C) CONTENT. Amer. Soc. Hort. Sci. Proc. (1936) 34: 543–552.

(76) Mathiesen, E.
1938–39. [VITAMIN C IN NORWEGIAN FRUIT AND VEGETABLES, IN FRESH AND CANNED STATE.] Tidsskr. Hermetikkindus. 24: 410–420; 25: 18–28. [English summary, pp. 14–15.] [Chem. Abs. 33: 2237. 1939.]

(77) Matlack, M. B., and Sando, C. E.
1934. A CONTRIBUTION TO THE CHEMISTRY OF TOMATO PIGMENTS. THE COLORING MATTER IN AMERICAN RED AND PURPLE TOMATOES (LYCOPERSICUM ESCULENTUM). Jour. Biol. Chem. 104: 407–414, illus.

(78) Matsuoka, T.
1936. STUDIES ON VITAMIN C. XVIII. THE EFFECT OF LIGHT UPON THE PRODUCTION OF VITAMIN C. Agr. Chem. Soc. Japan Jour. 12: 1203–1210. [English abstract, pp. 160–161.] [Chem. Abs. 31: 3103. 1937.]

(79) Mayfield, H. L., and Richardson, J. E.
1940. ASCORBIC ACID CONTENT OF PARSNIPS. Food Res. 5: 361–368.

(80) Metcalfe, E., Rehm, P., and Winters, J.
1940. VARIATIONS IN ASCORBIC ACID CONTENT OF GRAPEFRUIT AND ORANGES FROM THE RIO GRANDE VALLEY OF TEXAS. Food Res. 5: 233–240.

(81) Miller, E. V., Winston, J. R., and Fisher, D. F.
1941. A PHYSIOLOGICAL STUDY OF CAROTENOID PIGMENTS AND OTHER CONSTITUENTS IN THE JUICE OF FLORIDA ORANGES. U. S. Dept. Agr. Tech. Bul. 780, 31 pp., illus.

(82) Mituda, H.
1938. STUDIES ON VITAMIN C. II. ON THE VARIATION OF THE VITAMIN C CONTENT IN SOME FRUITS. Agr. Chem. Soc. Japan Jour. 14: 1335–1340, illus. [Chem. Abs. 33: 7843. 1939.]

(83) Moldtmann, H. G.
1939. UNTERSUCHUNGEN ÜBER DEN ASCORBINSÄUREGEHALT DER PFLANZEN IN SEINER ABHÄNGIGKEIT VON INNEREN UND ÄUSSEREN FAKTOREN. Planta 30: 299–342.

(84) Morgan, A. F., and Smith, L. L. W.
1928. DEVELOPMENT OF VITAMIN A DURING RIPENING OF TOMATOES. Soc. Expt. Biol. and Med. Proc. 26: 44–47.

(85) Munsell, H. E.
1940. VITAMINS AND THEIR OCCURRENCE IN FOODS. Milbank Mem. Fund Quart. 18: 311–344.

(86) Murphy, E.
1939. VITAMIN C AND LIGHT. Amer. Soc. Hort. Sci. Proc. (1938) 36: 498–499.

(87) Naito, H., and Isimaru, K.
1938. ENZYMES IN FRUITS AND VEGETABLES. DETERMINATIONS OF ASCORBIC ACID AND ACTIVITY OF ITS OXIDASE IN TOMATO TISSUE. Inst. Phys. Chem. Res., Japan, Bul. 17: 797–812. [Chem. Abs. 33: 6903. 1939.]

(88) Olliver, M.
1938. THE ASCORBIC ACID CONTENT OF FRUITS AND VEGETABLES. Analyst 63: 2–18, illus.

(89) Ozetskiĭ, V. E., and Kefer, V. N.
1938. [THE ACCUMULATION OF COPPER IN CANNED TOMATOES AT VARIOUS STAGES IN THEIR PREPARATION.] Voprosy Pitaniya 7(3): 25–131. [Chem. Abs. 33: 2603. 1939.]

(90) Peragallo, I.
1935. SUL VALORE ALIMENTARE DEL SUCCO DI POMODORO. Quaderni della Nutr. 2: [387]–400, illus. [Nutr. Abs. and Rev. 6: 57. 1936.]

(91) Piegai, A.
1939. [COPPER IN CANNED TOMATOES.] Indus. Ital. delle Conserve Aliment. 14: [27]–36. [Chem. Abs. 33: 4690. 1939.]

(92) ———
1940. [THE PRESENCE OF ANTIRACHITIC VITAMIN IN THE FRUITS AND IN THE CONCENTRATE OF TOMATOES.] Indus. Ital. delle Conserve Aliment. 15: 23–28. [Chem. Abs. 34: 5956. 1940.]

(93) Plimmer, R. H. A., Raymond, W. H., and Lowndes, J.
1931. EXPERIMENTS ON NUTRITION.—XI, COMPARATIVE VITAMIN B_1 VALUES OF FOODSTUFFS: FRUITS AND VEGETABLES. Biochem. Jour. 25: 1788–1800.

(94) Poe, C. F., Gant, O. K., and Griffin, E.
1939. VITAMIN A CONTENT OF SOME COMMERCIALLY CANNED TOMATO JUICE. Fruit Prod. Jour. and Amer. Vinegar Indus. 19: 73, 74, illus.

(95) Reid, M. E., and Weintraub, R. L.
1939. SYNTHESIS OF ASCORBIC ACID IN EXCISED ROOTS OF THE WHITE MOONFLOWER. Science 89: 587–588.

(96) Reynolds, H.
1938. ASCORBIC ACID CONTENT OF ARKANSAS TOMATO JUICES. Ark. Agr. Expt. Sta. Ann. Rpt. 50 (Bul. 368): 67–68.

(97) ———
1940. ASCORBIC ACID CONTENT OF ARKANSAS TOMATO JUICES. Ark. Agr. Expt. Sta. Ann. Rpt. 51 (Bul. 386): 68–69.

(98) Robinson, K. W.
1940. FACTORS AFFECTING THE VITAMIN C (ASCORBIC ACID) CONTENT OF FRUIT AND VEGETABLES. Med. Jour. Austral. 27: 786–788. [Chem. Abs. 34: 8093. 1940.]

(99) Rogers, E. C., and Matthews, D. B.
1938. THE VITAMIN C CONTENT OF CONNECTICUT HOME CANNED TOMATOES. Jour. Home Econ. 30: 114–116.

(100) Rosa, J. T.
1926. RIPENING OF TOMATOES. Amer. Soc. Hort. Sci. Proc. (1925) 22: 315–322.

(101) Roscoe, M. H.
1931. THE DISTRIBUTION OF THE VITAMIN B COMPLEX. III. FRUITS. Biochem. Jour. 25: [2050]–2055.

(102) Rothenheim, C. A., Shaik Mahamud, H. S., and Cowlagi, S. S.
1938. VITAMIN C CONTENTS OF INDIAN FOODSTUFFS. CHILLIES (CAPSICUM). Indian Chem. Soc. Jour. 15: [15]–19. [Chem. Abs. 32: 4680. 1938.]

(103) Sage, C. E., and Stevens, S. G. E.
1938. COPPER IN TOMATO PRODUCTS. (Note) Analyst 63: 719.

(104) Sanborn, N. H.
1938. CONSERVATION OF VITAMIN C IN TOMATO JUICE PRODUCTION. Glass Packer 17: 102–103.

(105) Sándor, Z.
1935. A PARADICSOMRÓL. (ÖSSZETÉTELE KÉSZÍTMÉNYEI, RAKTÁROZÁSA; KÜLÖNÖS TEKINTETTEL AZ ILLÓSAVTARTALOMRA.) Mezögazdasági Kutatások 8: 7–28.

(106) Sansome, F. W., and Zilva, S. S.
1933. POLYPLOIDY AND VITAMIN C. Biochem. Jour. 27: 1935–1941, illus.

(107) Saywell, L. G., and Cruess, W. V.
1932. THE COMPOSITION OF CANNING TOMATOES. Calif. Agr. Expt. Sta. Bul. 545, 32 pp., illus.

(108) ——— and Robertson, D. P.
1932. CARBOHYDRATE CONTENT OF TOMATO FRUIT. Plant Physiol. 7: 705–710.

(109) Schätzlein, C., and Fox-jimmling, E.
1940. UNTERSUCHUNGEN ÜBER DEN VITAMIN C-GEHALT VON GEMÜSE UND OBST. Ztschr. f. Untersuch. der Lebensmtl. 79: 157–164.

(110) Scheunert, A., and Reschke, J.
1938. ÜBER DEN VITAMIN-C-GEHALT VON GEMÜSEN, WELCHE EINERSEITS MIT STALLDUNG, ANDERERSEITS MIT STALLDUNG+NPK GEDÜNGT WORDEN WAREN. Forschungsdienst 6: 34–48.

(111) ——— and Wagner, K. H.
1939. ÜBER DEN EINFLUSS DER DÜNGUNG AUF DEN VITAMIN-GEHALT (MIT QUANTITATIVEN VITAMIN A-BESTIMMUNGEN IN GRÜNKOHL, SPINAT, ROSENKOHL UND TOMATEN). Biochem. Ztschr. 303: [266]–285, illus.

(112) Shannon, W. J., and Englis, D. T.
1940. COPPER IN TOMATOES. Assoc. Off. Agr. Chem. Jour. 23: 678–680.

(113) Sherman, H. C.
1941. CHEMISTRY OF FOOD AND NUTRITION. Ed. 6, 611 pp., illus. New York.

(114) SHIVRINA, A. N.
1937. A STUDY OF VITAMINS C AND PRO-VITAMIN A (CAROTENE) IN TOMATO VARIETIES. Bul. Appl. Bot., Genet., and Plant Breeding, Sup. 84, Vitamin Prob. 2: 128–141, illus. [English summary *in* Summaries, p. 6.] [Chem. Abs. 33: 1366. 1939.]

(115) ———

(116) ——— and PROZOROVSKAYA, L. L.
1938. [RELATIVE CONTENT OF CAROTENOID PIGMENTS IN TOMATO VARIETIES.] Biokhimii͡a 3: 541–545. [German summary, p. 545.] [Chem. Abs. 33: 684. 1939.]
1937. VITAMIN A CONTENT IN SOME VEGETABLES. Bul. Appl. Bot., Genet., and Plant Breeding, Sup. 84, Vitamin Prob. 2: 242–247. [English summary *in* Summaries, p. 9.] [Chem. Abs. 33: 1404. 1939.]

(117) SMITH, M. E.
1936. FACTORS WHICH AFFECT THE QUALITY OF THE CANNED TOMATOES. Ark. Agr. Expt. Sta. Ann. Rpt. 48 (Bul. 337): 48–49.

(118) ———
1937. SEASONAL INFLUENCES WHICH AFFECT THE QUALITY OF CANNED TOMATOES. III. A STUDY OF THE PHYSICAL AND CHEMICAL CONSTITUENTS OF MARGLOBE TOMATOES. Fruit Prod. Jour. and Amer. Vinegar Indus. 16: 302–304, 336–337, 345, 364–366, 377, illus.

(119) SMITH, O.
1936. EFFECTS OF LIGHT ON CAROTENOID FORMATION IN TOMATO FRUITS. N. Y. (Cornell) Agr. Expt. Sta. Mem. 187, 26 pp., illus.

(120) SPOHN, A.
1931. THE ANTISCORBUTIC VITAMIN IN THE JUICE OF HOME-CANNED TOMATOES. Jour. Agr. Res. 43: 1109–1113, illus.

(121) STEENBOCK, H., and SCHRADER, I. M.
1931. FAT SOLUBLE VITAMINS.—XXXII, THE DISTRIBUTION OF VITAMIN A IN TOMATO AND THE STABILITY OF ADDED VITAMIN D. Jour. Nutr. 4: 267–279, illus.

(122) SUGAWARA, T.
1939. STUDIES ON THE FORMATION OF ASCORBIC ACID (VITAMIN C) IN PLANTS. I. THE INFLUENCE OF LIGHT ON THE ASCORBIC ACID CONTENTS IN VARIOUS ETIOLATED SEEDLINGS. Jap. Jour. Bot. 10: 141–150, illus.

(123) ———
1939. STUDIES ON THE FORMATION OF ASCORBIC ACID (VITAMIN C) IN PLANTS. II. THE INFLUENCE OF RADIATION OF DIFFERENT WAVE-LENGTHS ON THE ASCORBIC ACID CONTENTS IN ETIOLATED SEEDLINGS. Jap. Jour. Bot. 10: 325–333, illus.

(124) TAXNER, K.
1937. PARADICSOM SZÍNVIZSGÁLAT: MÓDSZEREK. [METHODS FOR THE DETERMINATION OF COLOR OF TOMATOES.] Kisérlet. Közlem. 40: [235]–247. [English summary, p. 247. English title from Chem. Abs. 32: 6350. 1938.]

(125) TISDALL, F. F., DRAKE, T. G. H., SUMMERFELDT, P., and JACKSON, S. H.
1937. THE COMPARATIVE VALUE OF SPINACH AND TOMATOES IN THE CHILD'S DIET. Jour. Ped. 11: 374–384, illus.

(126) TODHUNTER, E. N.
1936. SOME FACTORS INFLUENCING ASCORBIC-ACID (VITAMIN-C) CONTENT OF APPLES. Food Res. 1: 435–442.

(127) TRESSLER, D. K.
1938. IMPORTANCE OF REFRIGERATION IN CONSERVING THE VITAMIN C CONTENT OF FRESH VEGETABLES. Ice and Cold Storage 41: 141–142. [Chem. Abs. 33: 6465. 1939.]

(128) ——— and CURRAN, K. M.
1938. THE CAUSE OF LOSS OF VITAMIN C FROM BOTTLED TOMATO JUICE. Jour. Home Econ. 30: 487, 488.

(129) ——— MACK, G. L., and KING, C. G.
1936. FACTORS INFLUENCING THE VITAMIN C CONTENT OF VEGETABLES. Amer. Jour. Pub. Health 26: 905–909, illus.

(130) TRIPP, F., SATTERFIELD, G. H., and HOLMES, A. D.
1937. VARIETAL DIFFERENCES IN THE VITAMIN C (ASCORBIC ACID) CONTENT OF TOMATOES. Jour. Home Econ. 29: 258–262.

(131) TSUGE, H., and KURIHARA, K.
1937. THE FORMATION OF VITAMIN C AND BEZSSONOFF-POSITIVE SUBSTANCES DURING GERMINATION OF GREEN BEANS, YAENARISASAGE. Sei-i-Kai Med. Jour. 56: 894–903. [Chem. Abs. 31: 8610. 1937.]
(132) UNITED STATES DEPARTMENT OF AGRICULTURE.
1941. AGRICULTURAL STATISTICS, 1941. 731 pp. Washington, [D. C.]
(133) VESELKINE, N. V., LUBIMENKO, V. N., BOULGAKOVA, Z. P., and others.
1934. [THE ACTION OF LIGHT ON THE SYNTHESIS OF VITAMINS.] [Leningrad] Nauch. Inst. Lesgafta Izv. 17/18: 389–404.
(134) ——— LUBIMENKO, V. N., BOULGAKOVA, Z. P., and others.
1934. [THE ACTION OF LIGHT ON THE SYNTHESIS OF VITAMIN C.] [Leningrad] Nauch. Inst. Lesgafta Izv. 17/18: 405–410.
(135) VIRTANEN, A. I., and EEROLA, L. V.
1936. FORMATION OF VITAMIN C IN GERMINATING SEEDS. Suomen Kem. 9B: 13–14. [Chem. Abs. 31: 2254. 1937.]
(136) VOGELE, A. C.
1937. EFFECT OF ENVIRONMENTAL FACTORS ON COLOR OF THE TOMATO AND WATERMELON. Plant Physiol. 12: 929–955.
(137) WACHHOLDER, K., and NEHRING, K.
1938. ÜBER DEN VITAMIN-C-GEHALT VERSCHIEDENER KARTOFFELSORTEN UND SEINE ABHÄNGIGKEIT VON DER DÜNGUNG. Bodenk. u. Pflanzenernähr. 9/10: 709–724, illus.
(138) ——— and NEHRING, K.
1940. ÜBER DEN EINFLUSS VON DÜNGUNG UND BODEN AUF DEN VITAMIN C-GEHALT VERSCHIEDENER KARTOFFELSORTEN. 2. Bodenk. u. Pflanzenernähr. 16 (5/6): [245]-260.
(139) WATANABE, K.
1938. VITAMIN C STUDIES ON THE PINEAPPLE (ANANAS SATIVUS). Soc. Trop. Agr. Jour. 10: 67–75. [English résumé, p. 75.]
(140) WEBER, A. L., and McLEAN, H. C.
1939. COPPER CONTENT OF SOME NEW JERSEY GROWN TOMATOES. Amer. Soc. Hort. Sci. Proc. (1938) 36: 705–707.
(141) YARBROUGH, M., and SATTERFIELD, G. H.
1939. THE RELATIONSHIP OF ACIDITY TO THE VITAMIN C CONTENT OF TOMATOES. Ztschr. f. Vitaminforsch. 9: 209–212.
(142) YOFE, J., and YOFE, T.
1936. VITAMIN C IN CITRUS JUICES, SEASON 1935–36. Hadar 9: 230, 231.

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